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AUTHOR Pouler, Chris A.; Wright, Emmett
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ABSTRACT

The effects of instruction on the ability of children to generate written hypotheses and ask questions about variables pertaining to scientific discrepant events were investigated. Two hundred five ninth graders were assigned to a control group or one of four experimental instruction groups. The experimental instruction was received by watching a discrepant event until 6 acceptable hypotheses were written. The instructor then evaluated each of the 6 hypotheses by one of four predetermined standards which varied in reinforcement (either differentiated positive or no reinforcement) and criteria group (either mention or no mention of the criteria for good hypothesis formation). Following the instruction, all groups were shown two discrepant events and were requested to write hypotheses for one and questions for the other. Five days later another event was observed by each group; students then asked questions of the investigator which were answered yes or no. Conclusions regarding which method of instruction produced the best results when compared to no instruction involved predominantly the approaches of reinforcement alone and reinforcement plus criteria. Reinforcement was essential for greater quantity of written hypotheses; for quality, reinforcement plus knowledge of the criteria was superior to no instruction. Differences in short- and long-term applications were mentioned. (CS)

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THE EFFECT OF INTENSIVE INSTRUCTION IN HYPOTHESIS GENERATION UPON HYPOTHESIS FORMING AND QUESTIONING BEHAVIORS OF NINTH GRADE STUDENTS

By

Chris A. Pouler
Prince George's County Public Schools
Upper Marlboro, Maryland 20870

and

Emmett Wright
University of Maryland
College Park, Maryland

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INTRODUCTION

From youngsters' cries of WHY to probing questions from scientists and philosophers, the process of hypothesizing has occurred for generations and centuries throughout civilizations. Socrates, over 2,000 years ago, acknowledged the processes of division and generalization as essential to help him speak and think. And today, this expression is applied in classrooms as teachers attempt to develop the hypothesizing skills of their students. Unfortunately, however, the teachers do not always succeed. As evidence, consider the following story.

After completing a grammar lesson in the proper use of the exclamation point, a teacher allowed the students time for meditation. Two young men, from opposite sides of the room, decided to apply their recently acquired knowledge by writing a note to the girl sitting in front. One wrote the following: "i luv u!" The other wrote: "I hate you!" Although both students applied their lesson, in one note the grammar was wrong but the application was right while in the other the grammar was right but the application was wrong. And, that is the way it is! Students are taught concepts but are seldom properly instructed in application. Not that we--as science educators--must teach students WHAT to think but we are obligated to teach students HOW to think.

The inquiry approach to science teaching, developed in the 1960's, is intended to help students acquire and apply problem solving skills while discovering scientific concepts. Yet, success does not depend

upon the presence of the curriculum but by the way students are instructed to recognize the variables contained in problems and, ultimately, to generate hypotheses about possible solutions.

Occasionally teachers assume students perceive a problem when, actually, they do not. The resulting situation is much like that of the farmer who was unable to train his stubborn mule. After failing, he hired the best mule trainer in the world. Upon arriving, the trainer carefully examined the animal. Picking up a long piece of wood, the trainer implemented the training program by firmly striking the mule. "I hired you to train my mule not beat it to death," exclaimed the irate farmer! "True," calmly replied the trainer, "but, first I had to get its attention." Although utilizing interest instead of coercion, teachers must focus the attention of students. By using simple and clear discrepant events, which contain multivariabled explanations, students can be <u>taught</u> to isolate variables in such a way to generate a greater quality and quantity of hypotheses.

PURPOSE

The purpose of this presentation is to discuss the highlights of a study conducted to determine how intensive instruction in hypothesis formation can produce a greater quality and quantity of hypotheses and a greater quantity and diversity of questions about the variables pertaining to a scientific discrepant event.

PROCEDURE

Subjects

The participants were ninth grade students of Frederick Sasscer Junior High School in Upper Marlboro, Maryland. As a school in suburban Washington, D. C., Frederick Sasscer is part of the Prince George's County Public School System which is one of the largest in the Nation.

Participation in both the initial investigation and the actual study was voluntary and required parental consent. A total of 205 students representing eleven intact classes were placed into five experimental groups with forty-one students each. The average age of the participants was 14 years and 8 months. In addition, prior to the study, students from another intact class were selected to participate in an initial investigation to determine the feasibility of the intensive instruction procedures.

Design

The design of the study involved:

a. randomly placing the subjects from each intact class into one of five experimental groups which were stratified according to the sex composition of each intact class,

b. introducing the subjects to the concept of hypothesis formation,

c. intensively instructing four of the experimental groups, and

d. determining the effect of intensive instruction on questioning and hypothesizing behaviors.

In order to present problems of sufficient interest and discrepancy, the Inquiry Development Program films (Suchman, 1966) were selected. Since only five films were necessary, it was important to select those which would present a clear problem or discrepant event to the greatest

number of students. On the basis of the existing science curriculum and advice from a panel, the following films were selected:

a. "The Restaurant"--to introduce the concept of hypotheses,

b. "The Knife"--to provide problems for intensive instruction,

c. "The Sailboat and The Fan"--to determine the effect of instruction on hypothesis formation,

d. "The Ice Cubes"--to determine the effect of instruction on questioning behaviors, and

e. "Drinking Boiling Coffee"--to determine the effect of instruction on group questioning behaviors and subsequent hypothesis formation.

Intensive Instruction

Intensive instruction was conducted in a large preparation/storage room. Arrangements were made to minimize distractions by providing a partitioned desk for each participant and, also, a set of headphones for listening to audiotaped instructions. In addition, the film was shown continuously on a screen visible by all students. Since two different groups received intensive instruction during a normal science class period, the procedure took five days. The treatment sequence was, therefore, randomized using the pattern prescribed by a Greco-Latin square design.

The intensive instruction groups varied in the amount of information each member received during individual discussions with the researcher. The control group only listened to general instructions about hypothesis formation and watched the introductory discrepant event--"The Restaurant." The procedures for the four instruction groups included:

a. listening to general instruction about hypothesis formation and watching the introductory discrepant event,

b. watching the intensive instruction discrepant event--"The Knife"--until six acceptable hypotheses were written, and

c. individual discussions during which the investigator evaluated each of the six hypotheses by one of the following predetermined standards:

1. differentiated reinforcement and criteria group--each of the hypotheses had to meet a predetermined level of acceptability and, after each was stated, the student was (a) positively reinforced (e.g. good, very good, excellent) and (b) told the criteria for acceptable hypothesis formation,

2. undifferentiated reinforcement and criteria group--each of the hypotheses had to meet a predetermined level of acceptability and, after each was stated, the student was only told the criteria for acceptable hypothesis formation,

3. differentiated reinforcement group--each of the hypotheses had to meet a predetermined level of acceptability and, after each was stated, the student was only positively reinforced, or

4. undifferentiated reinforcement group--had to generate six hypotheses and, after each was stated, the student received only acceptance (I can accept this hypothesis).

The criteria for acceptable hypothesis formation was any hypothesis which rated a three on the Hypothesis Quality Scale (Quinn, 1971). For differentiated reinforcement, hypotheses of levels three, four, and five were equivalent to good, very good, and excellent. In total, there were four independent variables--criteria (given and not given) and a form of reinforcement (differentiated and undifferentiated).

Dependent Variables

Upon completing the intensive instruction sessions, the participants, during their regular class period, were shown another Inquiry Development Program film ("The Sailboat and The Fan") and were requested to write as many hypotheses as possible. After five minutes, another film--"The Ice Cubes"--was shown and the participants were requested to write as many questions as possible which would provide information to help explain the discrepancy. Five days later, group discussions began using one experimental group during each class period until all the experimental

groups had completed the discussion (five days). During the discussion, the students observed another film--"Drinking Boiling Coffee"--and, then, had the opportunity to ask questions to the investigator about the discrepant event. The questions had to be specific so they could be answered with yes or no. After twenty questions, the discussion was terminated and the students were requested to individually write hypotheses that might explain the discrepancy.

Thus, this study gathered data about seven dependent variables:

a. both the quantity and quality of written hypotheses following intensive instruction,

b. both the quantity and diversity of written information search questions following intensive instruction,

c. the diversity of information search questions during the group discussion, and

d. both the quantity and quality of written hypotheses after the group discussion.

Statistical Analyses

The dependent variables for the written questions and hypotheses for each participant of the various experimental groups were analyzed by planned comparisons (contrasts) for the main effects interactions and treatment versus nontreatment comparisons. As significant differences occurred, either the Newman-Keuls or Dunnett test was conducted to determine the extent. The level of significance to support the various research hypotheses was 0.05.

To determine the dependent variable of question diversity during the group discussion, an analysis of variance and both the Newman-Keuls and Dunnett tests were conducted.

Quantity of Hypotheses and Questions

The measure for quantity was the number of nonrepeatable hypotheses and questions. In the event of an incomplete sentence, it was counted as part of the total quantity only if the meaning was understood so to be rated.

Quality of Hypotheses

Since the scale developed by Quinn (1971) was validated and, further, proven useful in analyzing hypotheses of both elementary (Quinn, 1971) and secondary (Wright, 1974) students, it was selected as the quality measure. Each hypothesis was given a point value corresponding to a category of the scale. These numbers were averaged to determine the quality of hypothesis generation for each individual.

Diversity of Questions

Suchman (1962b) devised a scale to determine the category of questions generated during an information search group discussion. Therefore, this scale was utilized. The Shannon Index was selected to calculate the diversity of questions because the various functions provided a concise means to express how the questions corresponded to the maximum diversity of the Suchman scale. Originally an information scale, the Shannon Index measured the uncertainty of predicting the specific identify of specific questions when drawing questions at random. Naturally, the higher diversity indicated greater uncertainty.

Correlation to the Measurement Scales

To assure the lack of prejudice on the part of the investigator in rating each hypothesis or question, two junior high science teachers were asked to rate fifteen hypotheses and questions randomly selected from

the responses of participants. Using Kendall's Coefficient of Concordance, the results of the teachers and the experimenter were compared. The coefficient values were 0.83 for hypotheses and 0.94 for questions.

FINDINGS OF THE STUDY

The findings supported many of the research hypotheses regarding the effect of intensive instruction on hypothesizing and questions behaviors. For each of the dependent variables, this study revealed the following.

Quantity of Written Hypothesis Generation Following Intensive Instruction

The methods of hypothesis generation intensive instruction which employed differentiated reinforcement were more effective than no intensive instruction in promoting a greater quantity of written hypotheses about a discrepant event following instruction (see Table 1). While differentiated reinforcement was superior to no instruction at all, there were no significant differences in the quantity of written hypotheses between the four intensive instruction groups.

Quality of Written Hypothesis Generation Following Intensive Instruction

Those participants who received differentiated reinforcement intensive instruction or undifferentiated reinforcement along with criteria intensive instruction produced a significantly higher quality of written hypotheses than participants who received (a) only undifferentiated reinforcement or (b) no intensive instruction (see Table 2). There was no significant difference between either of the differentiated reinforcement intensive instruction groups and the undifferentiated reinforcement/criteria

group. Therefore, in the presence of differentiated reinforcement, the addition of criteria as a condition of instruction does not enhance the quality of written hypothesis generation (see Figure 1).

Table 1.--Pair-wise analyses of experimental group data for the quantity of written hypotheses following instruction

		Newman-Keuls*				Dunnett**
Group	Mean	A 4.049	C 4.000	D 3.439	B 3.390	E 2.463
A[1]	4.049	-----	.1751	2.1801	2.3552	4.0080**
C[3]	4.000		-----	2.0049	2.1801	3.8842**
D[4]	3.439			------	.1751	2.4665
B[2]	3.390				------	2.3425
E[5]	2.463					------

*Significant at 0.05 when $t \geq 4.04$
**Significant at 0.05 when $t \geq 3.21$

[1]Group A: Differentiated Reinforcement and Criteria
[2]Group B: Undifferentiated Reinforcement and Criteria
[3]Group C: Differentiated Reinforcement only
[4]Group D: Undifferentiated Reinforcement only
[5]Group E: Control

Table 2--Pair-wise analyses of experimental group data for the quality of written hypotheses following intensive instruction

		Newman-Keuls*				Dunnett**
Group	Mean	B 2.856	C 2.764	A 2.667	D 2.131	E 1.853
B[2]	2.856	-----	.7858	1.6143	6.1924*	6.0631**
C[3]	2.764		------	.8285	5.4066*	5.5070**
A[1]	2.667			------	4.5781*	4.9206**
D[4]	2.131				------	1.6805
E[5]	1.853					

*Significant at .05 when $t \geq 4.04$
**Significant at .05 when $t \geq 3.21$

[1]Group A: Differentiated Reinforcement and Criteria
[2]Group B: Undifferentiated Reinforcement and Criteria
[3]Group C: Differentiated Reinforcement only
[4]Group D: Undifferentiated Reinforcement only
[5]Group E: Control

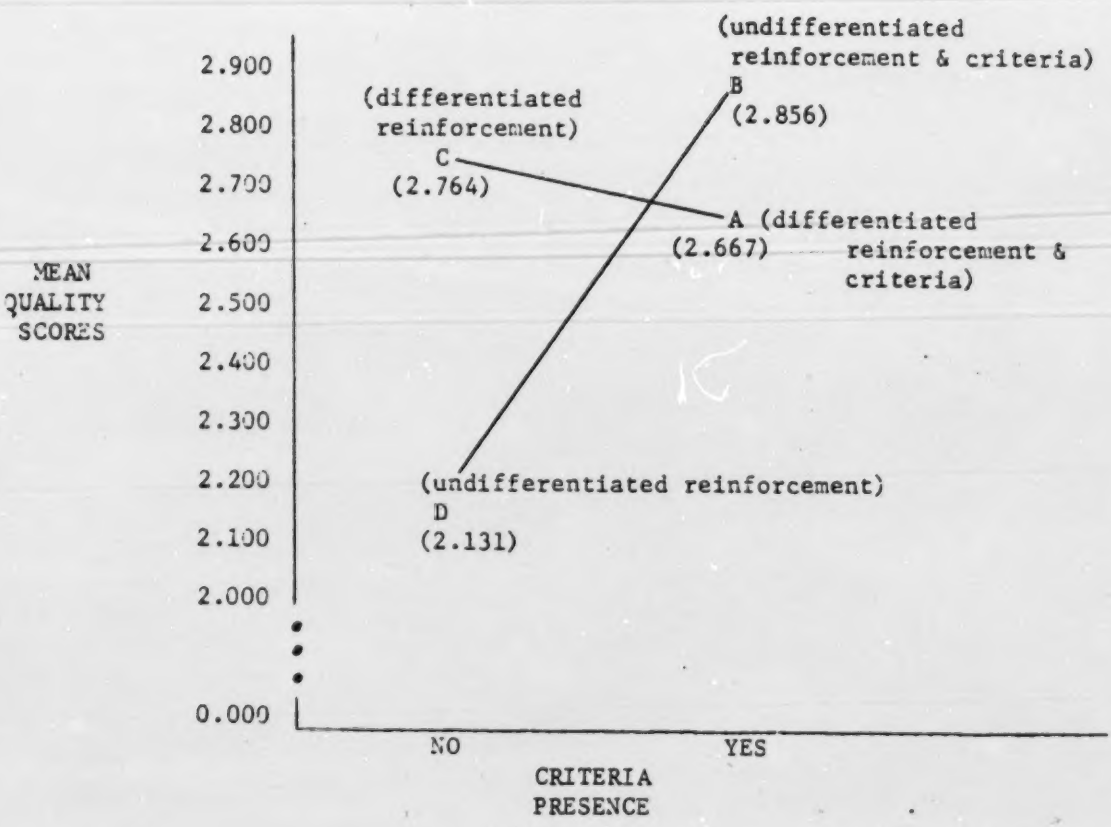

Fig. 1--Interaction Graph of Treatments

Quantity and Diversity of Written Information Search Questions Following Intensive Instruction

None of the four methods of hypothesis generation intensive instruction improved the ability of the participants to generate a significantly higher quantity or diversity of written information search questions about a discrepant event following intensive instruction (see Table 3-6).

Table 3.--Pair-wise comparisons of the experimental groups for the quantity of information search questions following intensive instruction

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	Probability (less than)
Treatment vs. Control	1	46.849	46.849	7.880	.005*
Interaction	1	1.976	1.976	.332	.565
Differentiated Reinforcement vs. Undifferentiated Reinf.	1	.390	.390	.066	.798
Criteria vs. no Criteria	1	.610	.610	.103	.749
Error	200	1189.073	5.945		
Total	204	1238.898			

*Significant at 0.05

Table 4.--Pair-wise analyses of experimental group data for the quantity of written information search questions following intensive instruction

Group	Mean	E(Dunnett**) 3.902
C[3]	5.220	2.4475
B[2]	5.195	2.4010
D[4]	5.098	2.2209
A[1]	4.878	1.8125
E[5]	3.902	------

**Significant at 0.05 when $t \geq 3.21$

[1]Group A: Differentiated Reinforcement and Criteria
[2]Group B: Undifferentiated Reinforcement and Criteria
[3]Group C: Differentiated Reinforcement only
[4]Group D: Undifferentiated Reinforcement only
[5]Group E: Control

Table 5.—Pair-wise comparisons of the experimental groups for the diversity of information search questions following intensive instruction

Source	Degrees of Freedom	Sum of Squares	Mean Square	F	Probability (less than)
Treatment vs. Control	1	.703	.703	4.919	.028*
Interaction	1	.000	.000	.001	.981
Differentiated Reinforcement vs. Undifferentiated Reinf.	1	.026	.026	.180	.672
Criteria vs. no Criteria	1	.139	.139	.973	.325
Error	200	28.566	.143		
Total	204	29.434			

*Significant at 0.05

Table 6.--Pair-wise analyses of the experimental group data for the diversity of information search questions following intensive instruction

Group	Mean	E (Dunnett**) .6079
A[1]	.7966	.7145
B[2]	.7702	.6145
C[3]	.7370	.4888
D[4]	.7134	.3994
E[5]	.6079	-----

*Significant at .05 when $t \geq 3.21$

[1]Group A: Differentiated Reinforcement and Criteria
[2]Group B: Undifferentiated Reinforcement and Criteria
[3]Group C: Differentiated Reinforcement only
[4]Group D: Undifferentiated Reinforcement only
[5]Group E: Control

Quantity of Written Hypothesis Generation After the Group Discussion

Intensive instruction which utilized only differentiated reinforcement was found more effective than no intensive instruction for promoting a higher quantity of written hypotheses after the information search group discussion (see Table 7). Again, there were no significant differences among the four intensive instruction groups.

Table 7.--Pair-wise analyses of experimental group data for the quantity of written hypotheses after the group discussion

		Newman-Keuls*				Dunnett**
Group	Mean	C 3.293	B 2.805	D 2.341	A 2.293	E 1.902
C[3]	3.293	-----	1.7045	3.3250	3.4927	3.4353**
B[1]	2.805		------	1.6206	1.7882	2.2301
D[4]	2.341			------	.1676	1.0842
A[1]					------	.9656
E[5]	1.902					------

*Significant at .05 when $t \geq 4.04$
**Significant at .05 when $t \geq 3.21$

[1]Group A: Differentiated Reinforcement and Criteria
[2]Group B: Undifferentiated Reinforcement and Criteria
[3]Group C: Differentiated Reinforcement only
[4]Group D: Undifferentiated Reinforcement only
[5]Group E: Control

Quality of Written Hypothesis Generation After the Group Discussion

Participants who were told the criteria for acceptable hypothesis generation (either with differentiated or undifferentiated reinforcement) produced a higher quality of written hypotheses after the group discussion than participants who (a) received only undifferentiated reinforcement or (b) received no intensive instruction. There was no difference in the quality of hypotheses when each criteria group was compared to the differentiated reinforcement group (see Table 8).

Table 8.--Pair-wise analyses of experimental group data for the quality of written hypotheses after the group discussion

		Newman-Keuls*				Dunnett**
Group	Mean	B 2.815	A 2.798	C 2.590	D 2.234	E 2.087
B[2]	2.815	-----	.1224	1.6199	4.1829*	3.7061**
A[1]	2.798		------	1.4975	4.0605*	3.6196**
C[3]	2.590			------	2.5630	2.5607
D[4]	2.234				------	.7484
E[5]						------

*Significant at 0.05 when $t \geq 4.04$
**Significant at 0.05 when $t \geq 3.21$

[1]Group A: Differentiated Reinforcement and Criteria
[2]Group B: Undifferentiated Reinforcement and Criteria
[3]Group C: Differentiated Reinforcement only
[4]Group D: Undifferentiated Reinforcement only
[5]Group E: Control

Diversity of Information Search Questions During the Group Discussion

None of the four forms of hypothesis generation intensive instruction significantly effected the diversity of questions submitted during a group discussion when compared to no intensive instruction (see Table 9).

Table 9.--Pair-wise analysis of data for diversity of information search questions during the group discussion

			Newman-Keuls*				Dunnett**
Group	Standard Deviation	Mean	D .8755	A .8736	C .8564	B .8452	E .7802
D[4]	0.0370	.8755	-----	.0823	.8271	1.3120	2.9180
A[1]	0.0684	.8736		-----	.7448	1.2298	2.8598
C[3]	0.0649	.8565			-----	.4893	2.3362
B[2]	0.0435	.8452				------	1.9902
E[5]	0.0547	.7802					------

*Significant at 0.05 when $t \geq 4.04$
**Significant at 0.05 when $t \geq 3.21$

[1]Group A: Differentiated Reinforcement and Criteria
[2]Group B: Undifferentiated Reinforcement and Criteria
[3]Group C: Differentiated Reinforcement only
[4]Group D: Undifferentiated Reinforcement only
[5]Group E: Control

CLOSING THOUGHTS

The preceeding findings indicated that hypothesis formation skills can be improved as a result of intensive instruction. The important implications, however, are those which apply directly for classroom instruction.

In this regard, the primary thrust is which of the methods of intensive instruction produced the best results when compared to no instruction. Certainly, the two approaches of (a) reinforcement alone and (b) reinforcement plus criteria were predominant. Reinforcement as an instructional condition was essential for a greater quantity of written hypotheses during short-term application. Likewise for quality, reinforcement along with knowledge of the criteria was superior to no instruction. Therefore, if a teacher wishes to improve both the quality and quantity of hypothesis formation over a short period of time, reinforcement is sufficient. For the long-term application, however, the method of optimal intensive instruction is dichotomous. If quality is expected, students must have knowledge of the criteria. On the other hand, if a greater quantity of hypotheses is expected, instruction with reinforcement alone is superior to no instruction. It appears, then, that knowledge of criteria makes participants more selective about generated hypotheses. Therefore, if both short- and long-term quality are expected, the teaching approach must include knowledge of criteria for acceptable hypothesis formation.

As Horace Mann said: "If ever there was a cause, if ever there can be a cause worthy to be upheld by all the toil or sacrifice that the human heart can endure, it is the cause of education."

Thank you for the opportunity to share some of the highlights of this study. Since the cause of research into optimal means for promoting thinking is worthwhile, it is hoped that this study will provide a basis for future research.

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